BeAGLE paper thoughts

Mark D. Baker

14-Sept.-2019

1) Essential technical issues
2) Plots to consider
3) Existing text
4) Other items

BeAGLE technical issues (I)

- Finish debugging. Goals (making progress):
  - Fixed target and collider e+A at the same s should be the same.
    - Fraction of rerolled events
    - Distributions: E*, N_{nevap} etc.
  - Total four-momentum should be conserved in the collision.
- Basic issue causing these bugs
  - Treatment of an "on-mass-shell" nucleon inside a nucleus. Consistent Lorentz boosting.
  - Handled differently for e+A vs. (e+D and SRC e+A)

BeAGLE technical issues (II)

- Currently using old version: fluka2011.2b
  - There are some problems with this.
- Should switch to FLUKA 2011.2x.7 (2019)
  - A bit complicated. Need gcc8.3 but still want to link with EIC dynamic libraries made with earlier gcc.
  - Kolja Kauder proactively noticed this problem and may have already solved it! I will test his new version – and probably so should Wan once it looks OK to me.

Basic BeAGLE talks and writeups so far

- Basic BeAGLE fuctionality mostly talked about in eRD17 reports and talks so far:
- Written reports on BeAGLE (=DPMJetHybrid2) for July 2015-July 2019 under: https://wiki.bnl.gov/conferences/index.php/EIC-Detector-Proposals
  - June/July are better and are in LaTeX
- Talks also July 2015-July 2019 under: https://wiki.bnl.gov/conferences/index.php/Meetings

Basic eRHIC/HERMES Pythia tune to start

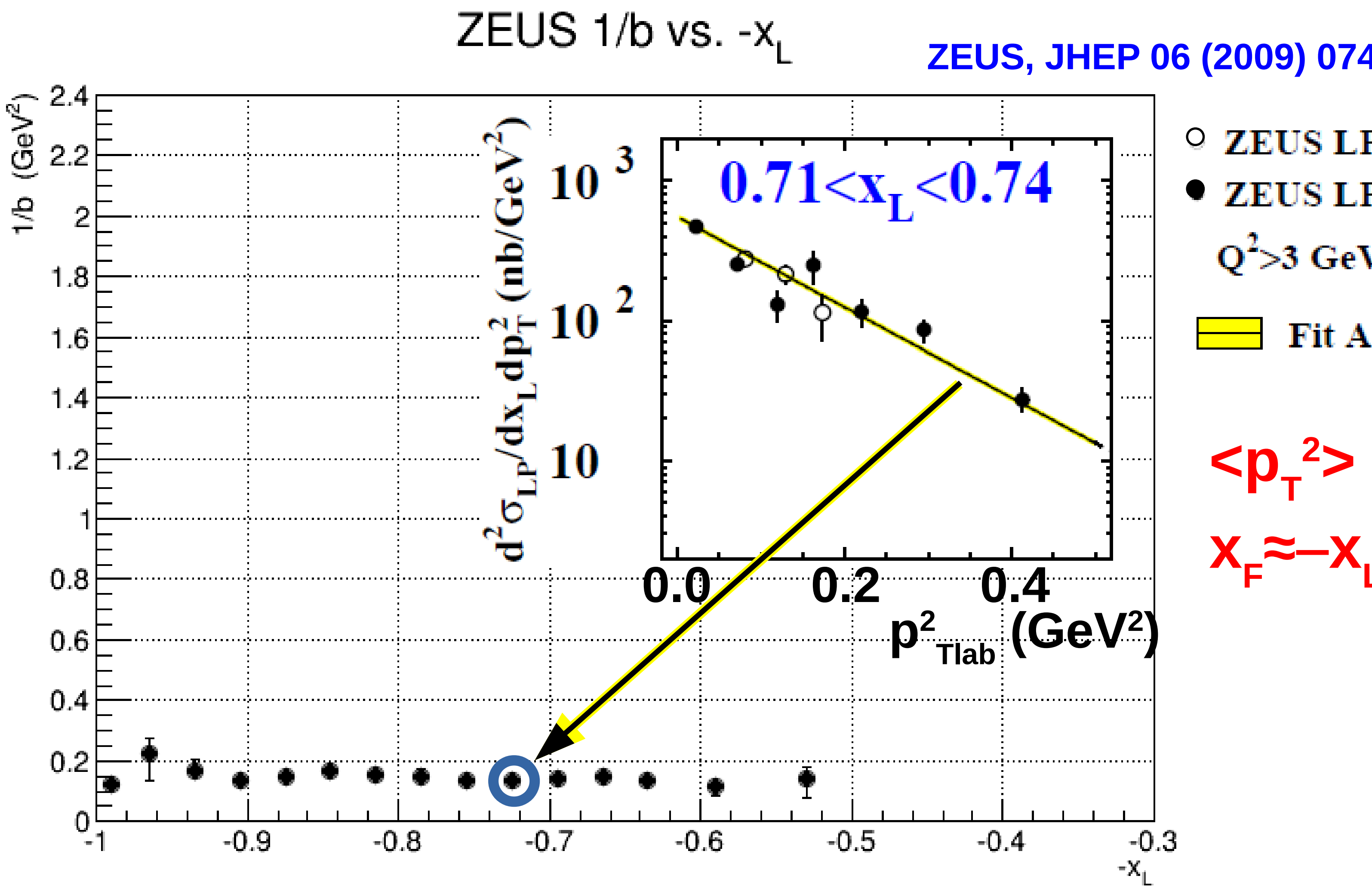
We use PARP(99)=0.4 (resolved photon kT D=1.0),
MSTJ(12)=1 (no popcorn) and some HERMES-inspired changes:
MSTP(19)=1, MSTP(20)=0, PARP(161)=3.0, PARP(162)=24.6, PARP(163)=18.8,
PARP(165)= 0.47679, PARP(2)=2.0, CKIN(1)=1.0.

Elke can explain why and/or point to the right reference.

Pythia tune for ZEUS e+p

- Fit to ZEUS forward protons $<p_T^2>$ & x_L
  - Still need to dig up plot of PARP(91) vs. PARJ(21) (intrinsic kt vs. fragmentation/cluster breakup pt)
- Fit to ZEUS forward neutrons x_L
  - MSTP(94)=3 vs.2.
  - For MSTP(94)=2: Range of PARP(97) (tune=6)
  - Existing plot doesn't show final tune (PARP(97)=6)
  - Existing plot doesn't show neutrons.

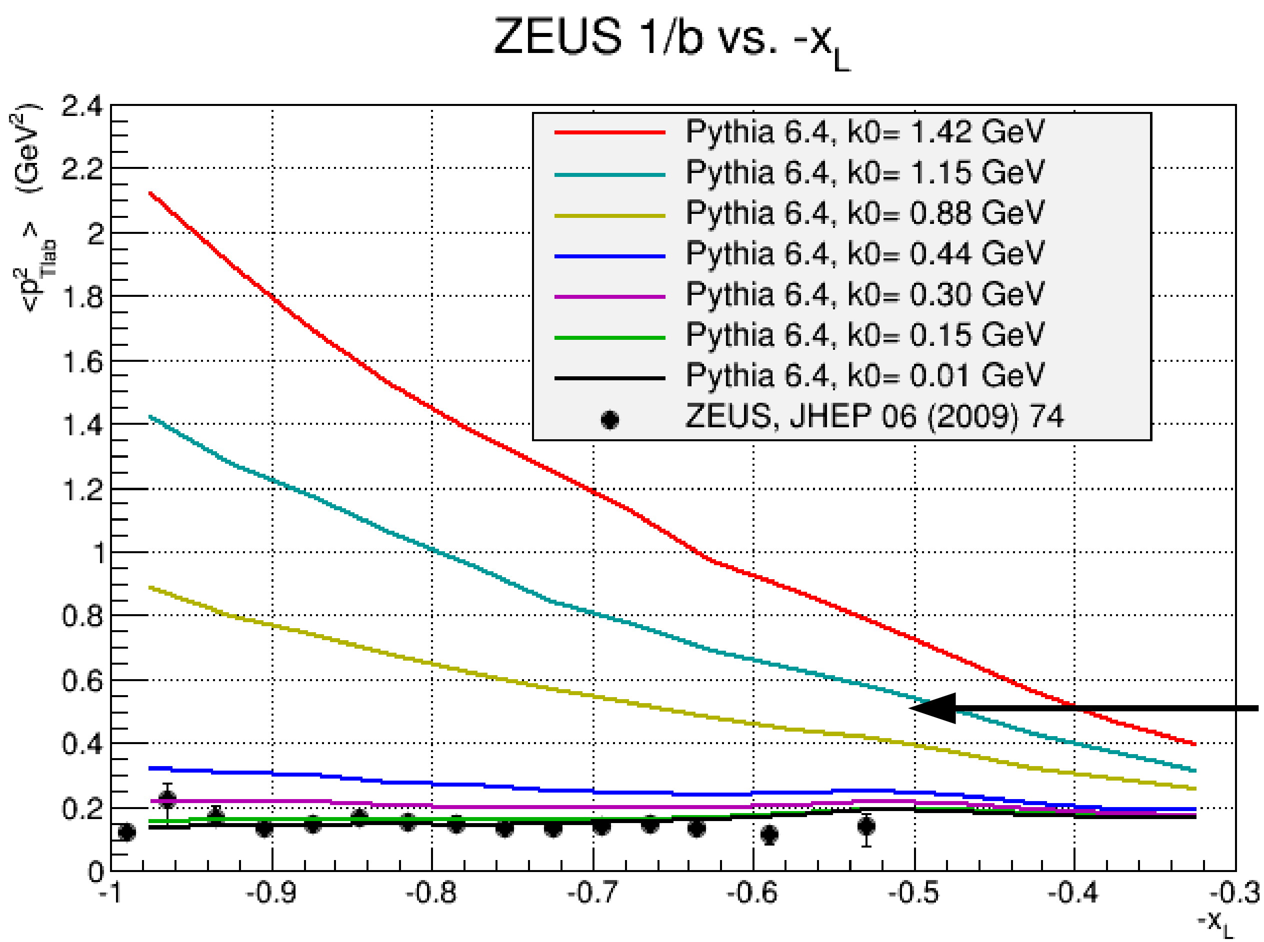
Laboratory "seagull" from ZEUS fits



$\langle p_T^2 \rangle$ = 1/b from fit

$x_F \approx -x_L$

Laboratory “seagull” from ZEUS



Pythia 6.4.28
EIC/BNL version

$k_0 = k_T^{rms} =$ PARP(91)

Default = 2.0 !

$k_0 \neq 1.42$ GeV

$k_0 \approx 0.01$ GeV

PROOF POSITIVE: The beam remnant jet is not contaminated by “QCD” effects

For more details see:

https://conferences.lbl.gov/event/56/session/8/contribution/40/material/slides/0.pdf

Phys./Tech. Goals #2 -A better Pythia for a better centrality tagging

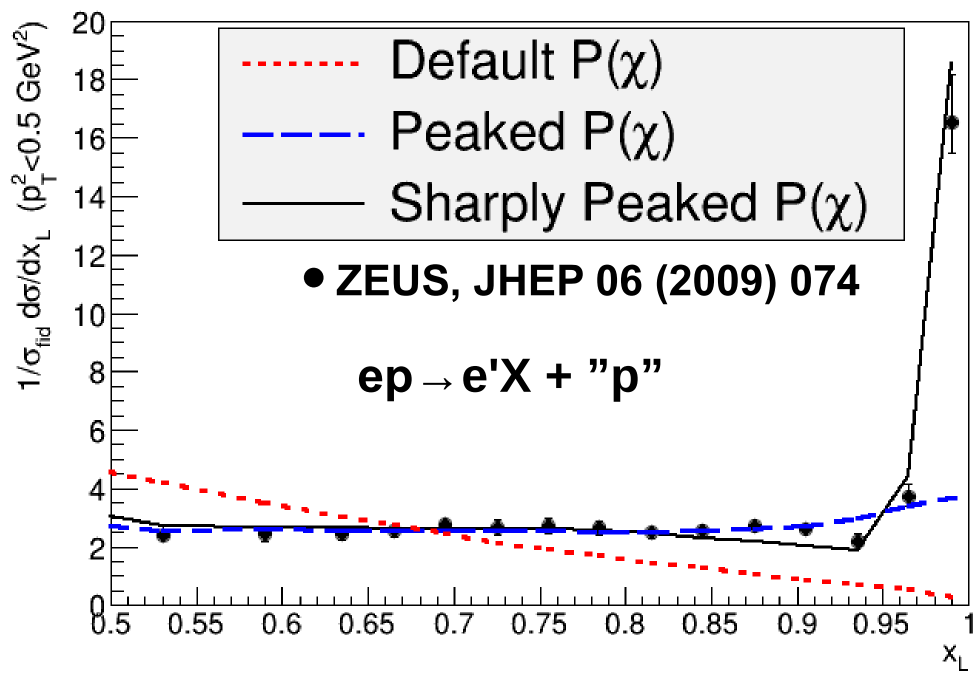
Non-trivial beam remnant clusters fragment into diquark+meson or baryon+quark. The p_L fraction carried by baryon/diquark is called χ.

We tuned $P(\chi)$ to better match ZEUS data. <u>More forward particles.</u>

	MSTP(94)	PARP(97)	$P(\chi)$
Default	3	-	Frag. function
Peaked	2	9	$10(1-\chi)^9$
Sharply	2	75	$76(1-\chi)^{75}$

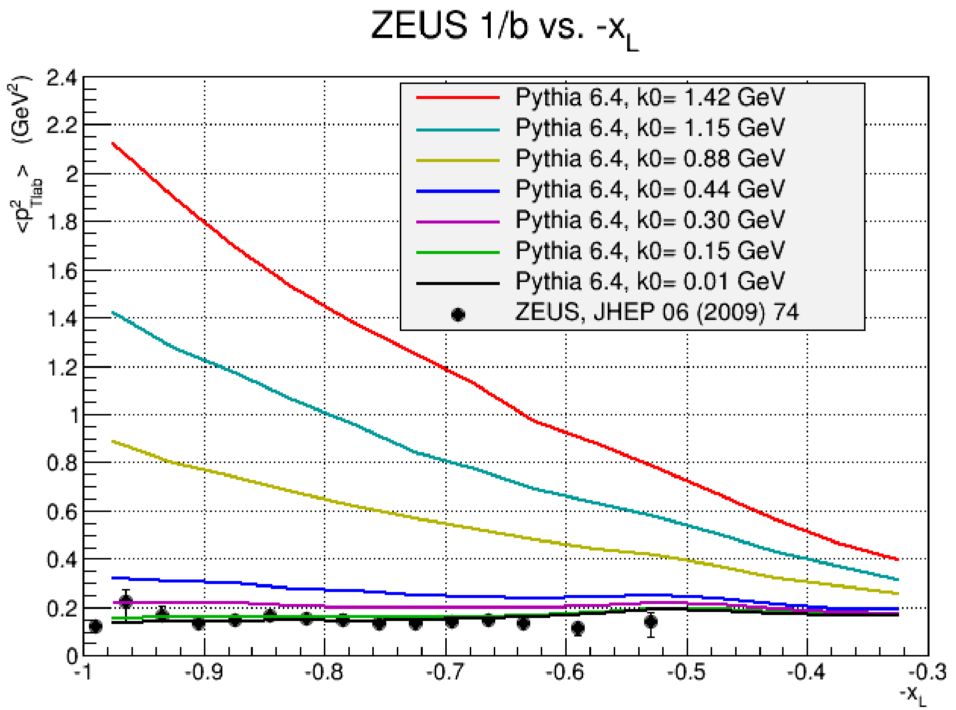
We also lowered k_T to better match ZEUS data. <u>More forward particles.</u>

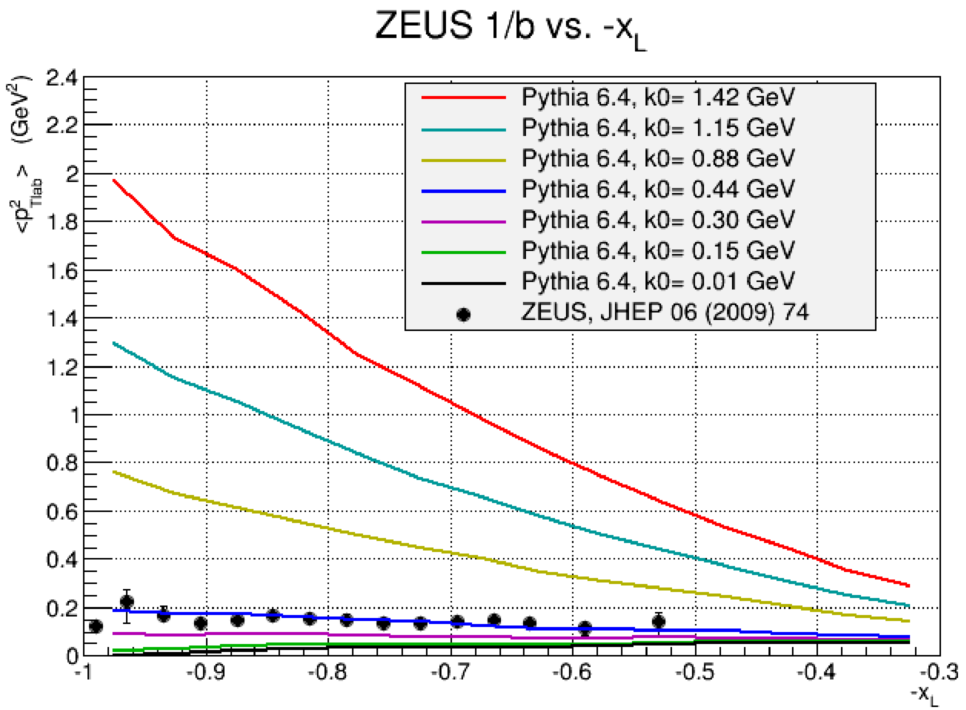
$\sigma_{fid} = \sigma$ **for h+ $0.5<x_L<0.89$, $p_T^2<0.5$ GeV^2**



NOTE: Seagull plot is NOT strongly affected by $P(\chi)$.

Fragmentation p_T vs intrinsic k_T



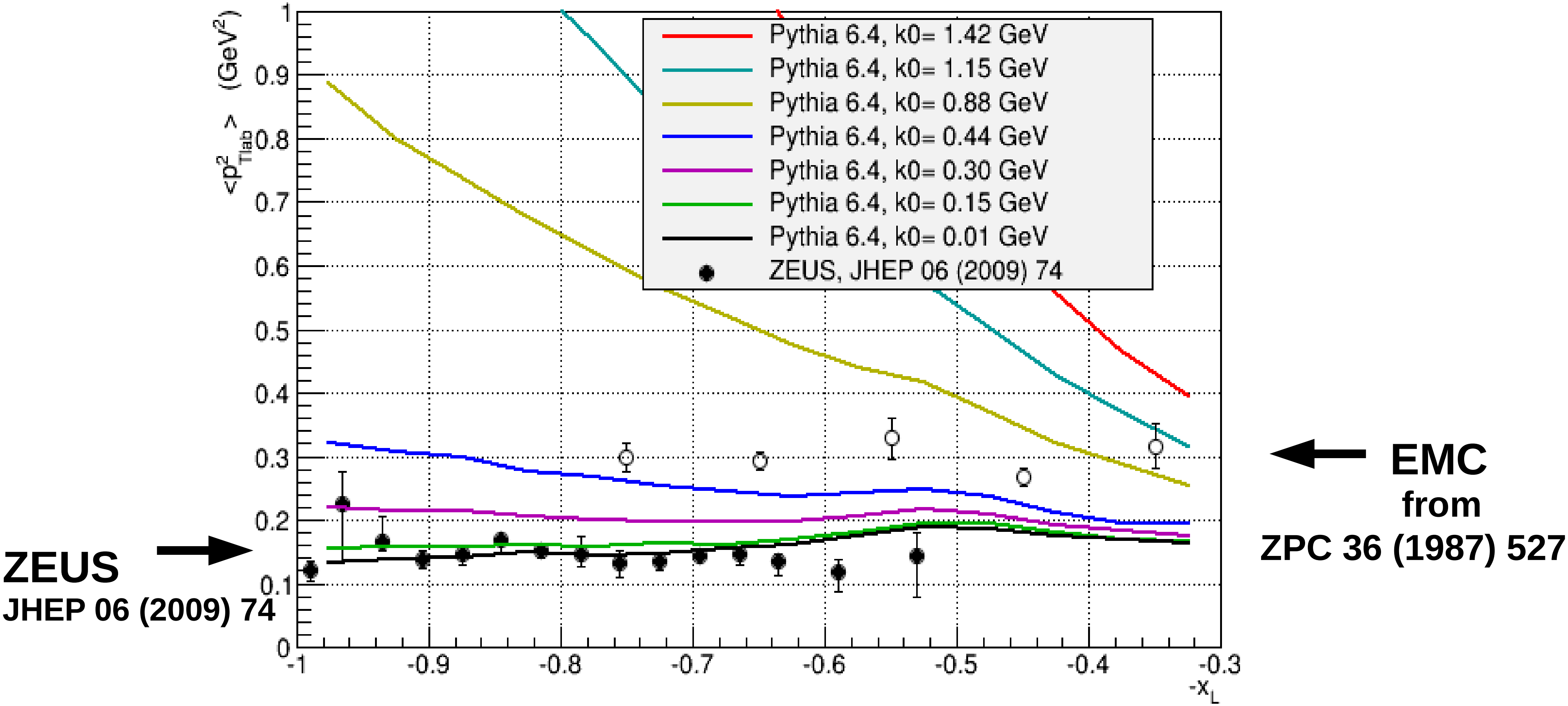


PARJ(21)=0.36 GeV (default) =
Fragmentation p_T AND
Beam remnant cluster breakup p_T
Data favors k_0=PARP(91)=0.01 GeV

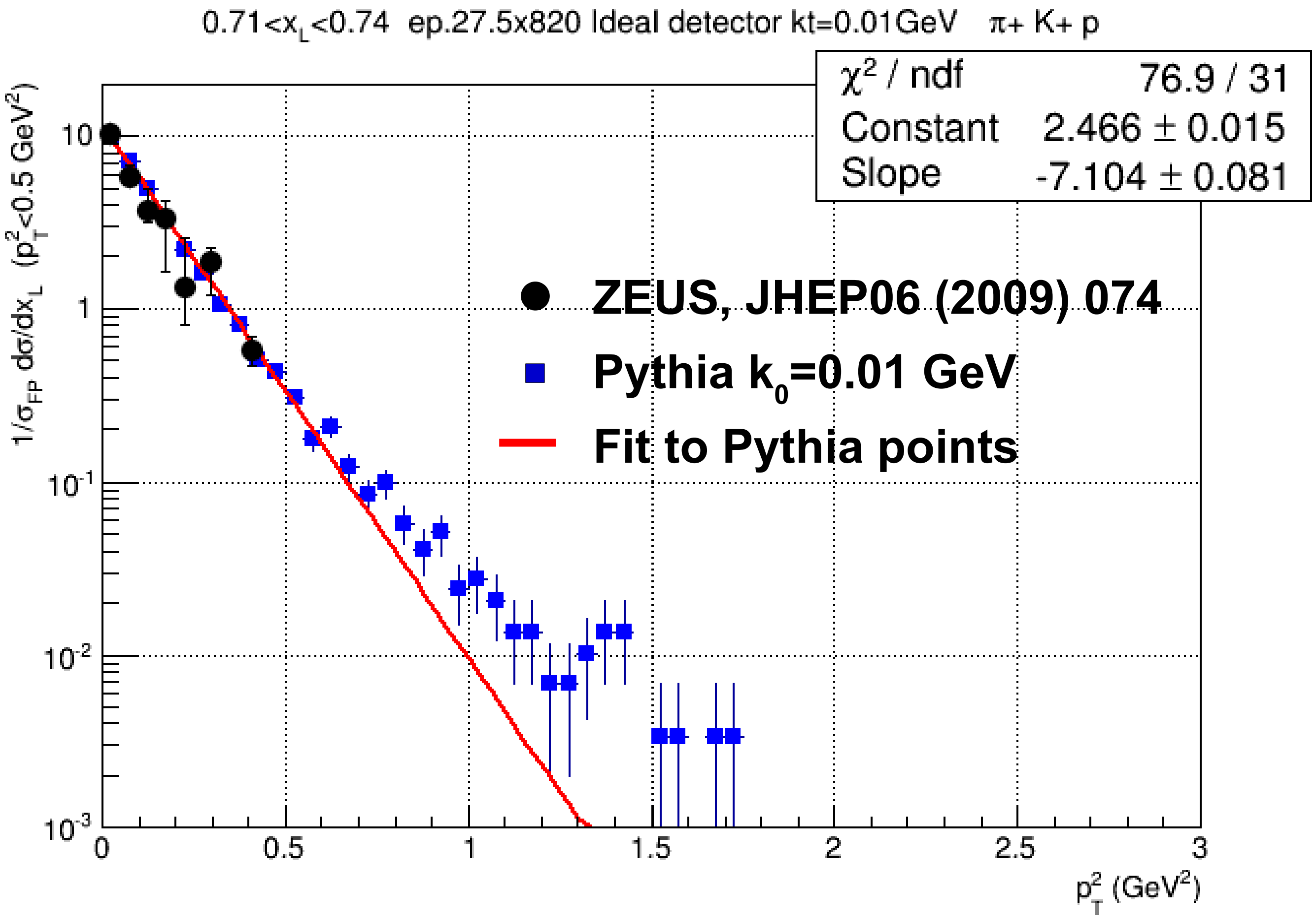
PARJ(21)=0.01 GeV (TINY!) =
Fragmentation p_T AND
Beam remnant cluster breakup p_T
Data favors k_0=PARP(91)=0.44 GeV

NOTE: In the end used PARJ(21)=PARP(91)=0.32

Hadron $<p_T^2>$: ZEUS = ½ EMC



ZEUS's acceptance is limited



EMC used a streamer chamber and a fixed target – nearly complete acceptance.

Non-gaussian tails For p_T^2>0.5 GeV^2 could explain k_T(ZEUS)<k_T(EMC)

New issue for an eA collider!

What is the momentum of the nucleon in a nucleus in the lab frame?
What is the mass of the proton inside the nucleus? Model dependent.
DPMJET & Pythia assume nucleons on-mass-shell.

Target Rest Frame

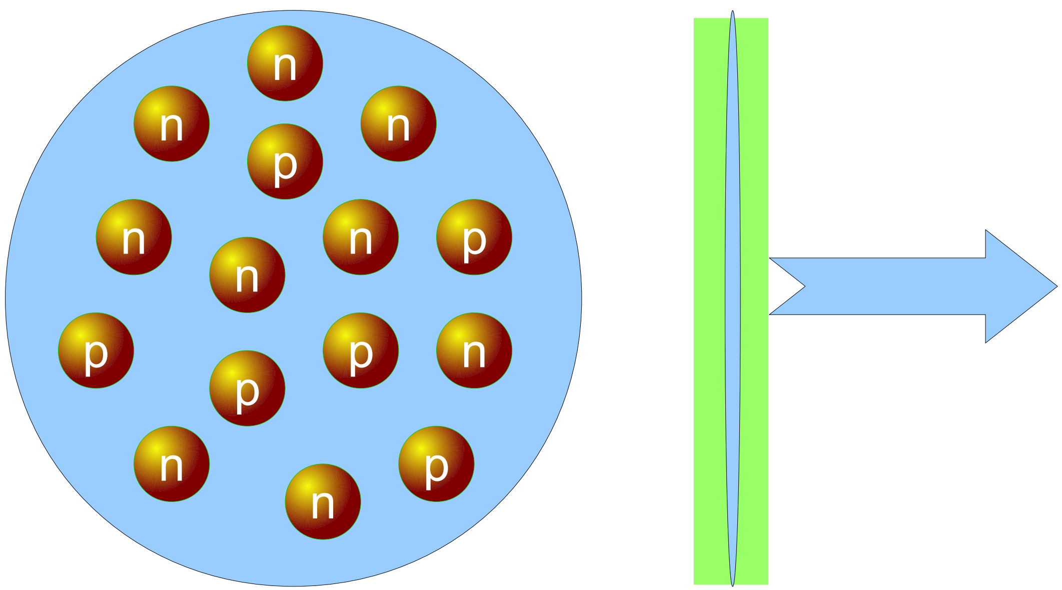
M_{Au}=197 x 0.99983 amu,   1amu=0.931494GeV

Laboratory Frame

p_{zAu}=197 x **100 GeV/c**

$\gamma\beta = p_z/M = 107.373$

$\gamma\beta \neq p_z/AM_p = 105.576$



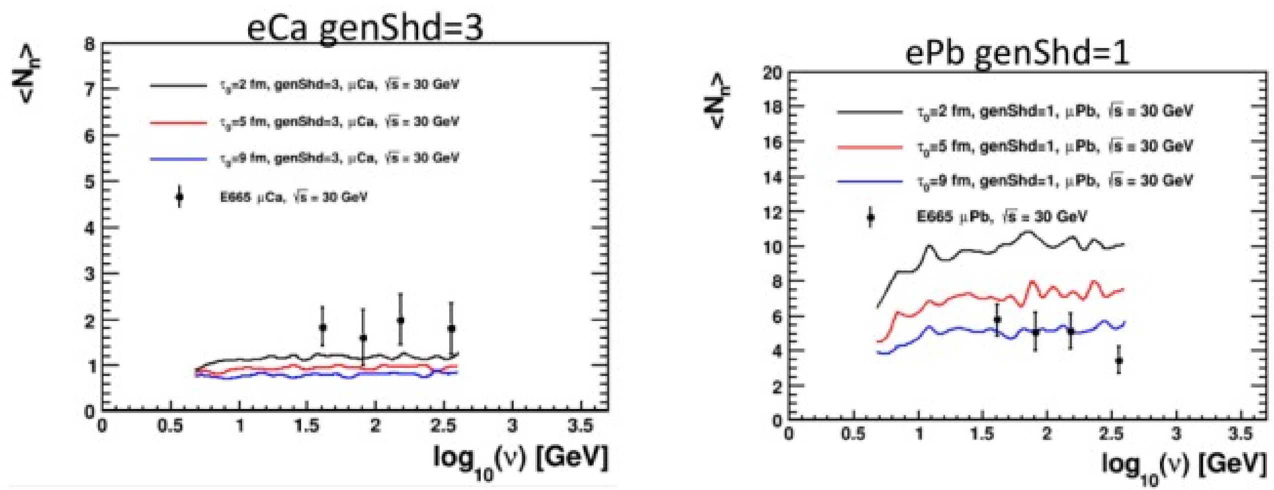
NOT 100 GeV!

M_p=1.0073 amu p $p_z(p)=\gamma\beta M_p$ = **100.75 GeV/c**

M_n=1.0087 amu n $p_z(n)=\gamma\beta M_p$ = **100.89 GeV/c**

Tune of τ_0

- <Nn> vs. $\log_{10}(\nu)$ for BeAGLE with a range of τ_0 and a range of assumptions for fraction f_{CD} of coherent diffraction in the data.
  - Locus of working values for f_{CD} vs. τ_0

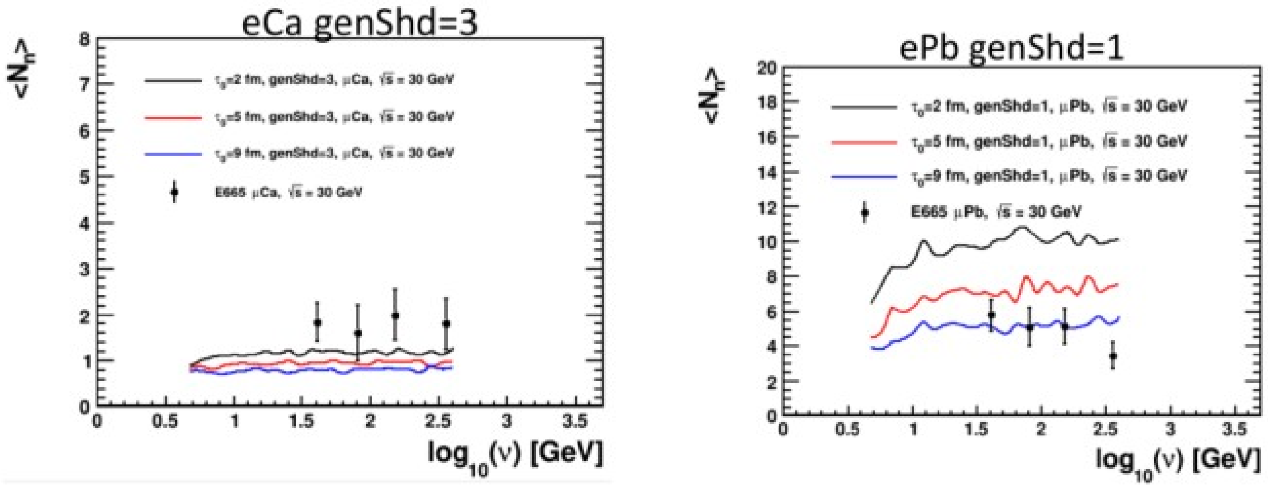


(a) Varying values of τ_0 for Ca (b) Varying values of τ_0 for Pb

Figure 3: Comparison of E665 (fixed target) soft neutron data adapted from Ref. [8] and different BeAGLE formation time parameter (τ_0) settings for: a) E665 $\mu + Ca$ data; b) E665 $\mu + Pb$ data.

Tune of τ_0

- Note: eCa was sensitive to genShd, ePb not.
- This was all $f_{CD}=0$.
  For $f_{CD}>0$, multiply theory curve by $(1-f_{CD})$
- Note: $f_{CD}(Ca) < f_{CD}(Pb)$ probably...



(a) Varying values of τ_0 for Ca

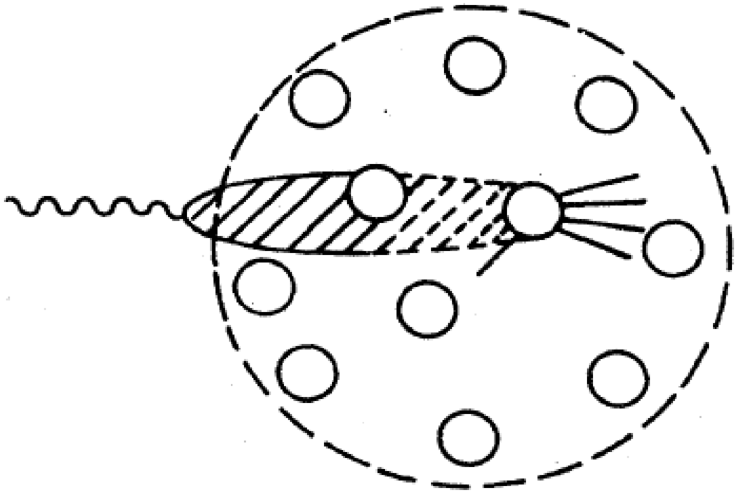
(b) Varying values of τ_0 for Pb

Figure 3: Comparison of E665 (fixed target) soft neutron data adapted from Ref. [8] and different BeAGLE formation time parameter (τ_0) settings for: a) E665 $\mu + Ca$ data; b) E665 $\mu + Pb$ data.

Shadowing

- These are plots that I'd better make. The rest (above) could/should be made by Wan with input from me if we want to avoid delays...

Basic idea of proposal



The virtual photon, in the target rest frame, can be treated as alternating between a point-like particle with σ~0 and a "dipole" or more complicated hadronic object with a larger σ (few mb). The coherence length of the "dipole" is λ~1/(2Mx). The fraction of the time it spends in this state is whatever fraction is needed for the total σ_{ep} to be correct.

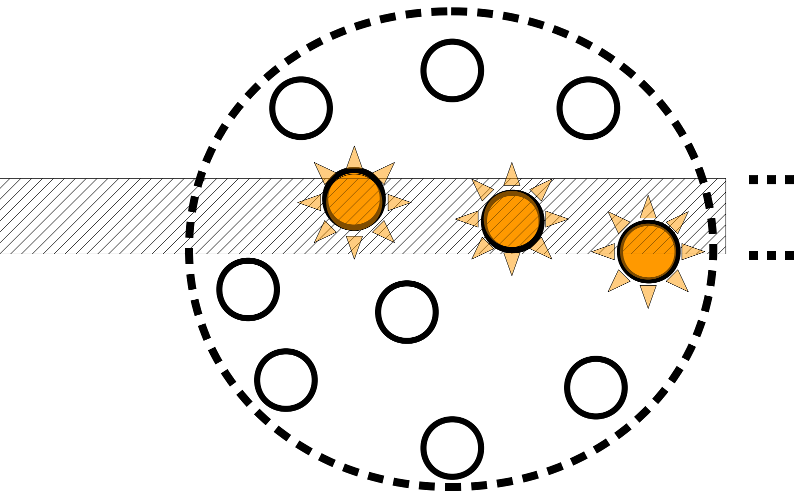
Do NOT model saturation in detail to find $\sigma_{dipole}(x,Q^2)$!

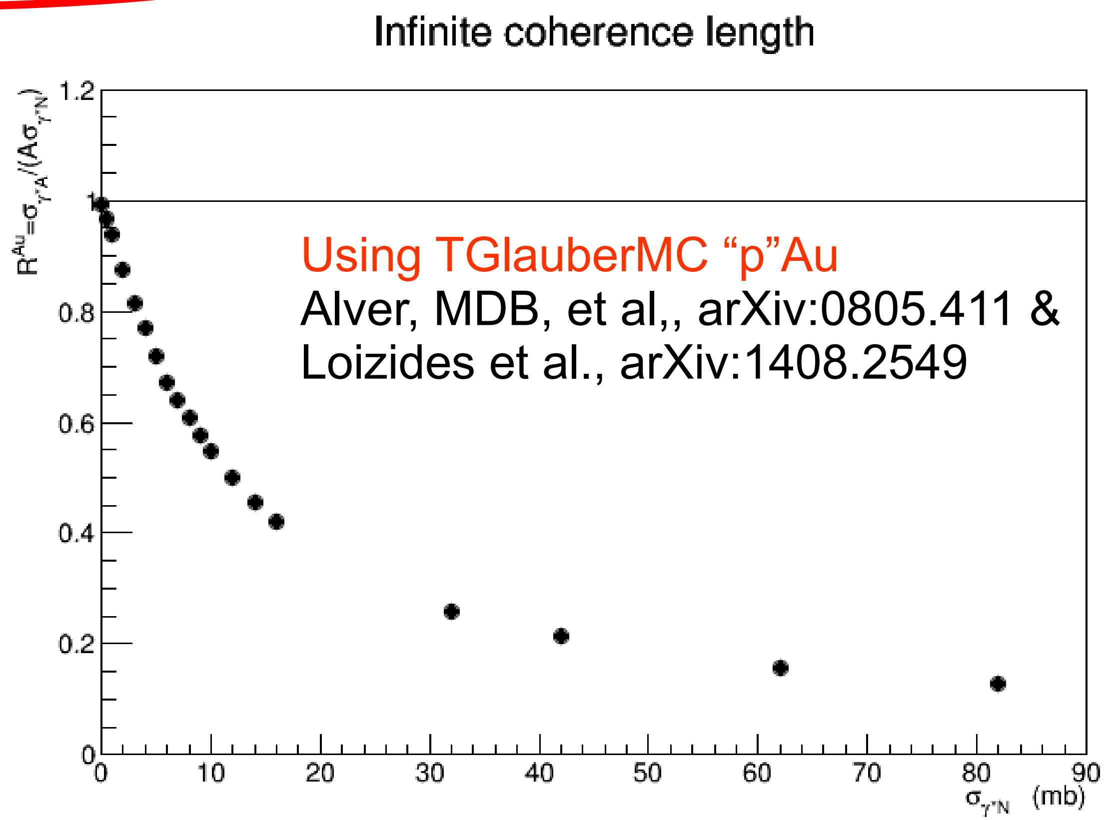
Rather, use an input value of nuclear shadowing $R^{Au}(x,Q^2)$ to find $\sigma_{dipole}(x,Q^2)$. Then model probability of multiple nucleon DIS.

Making the map for $\lambda >> R$

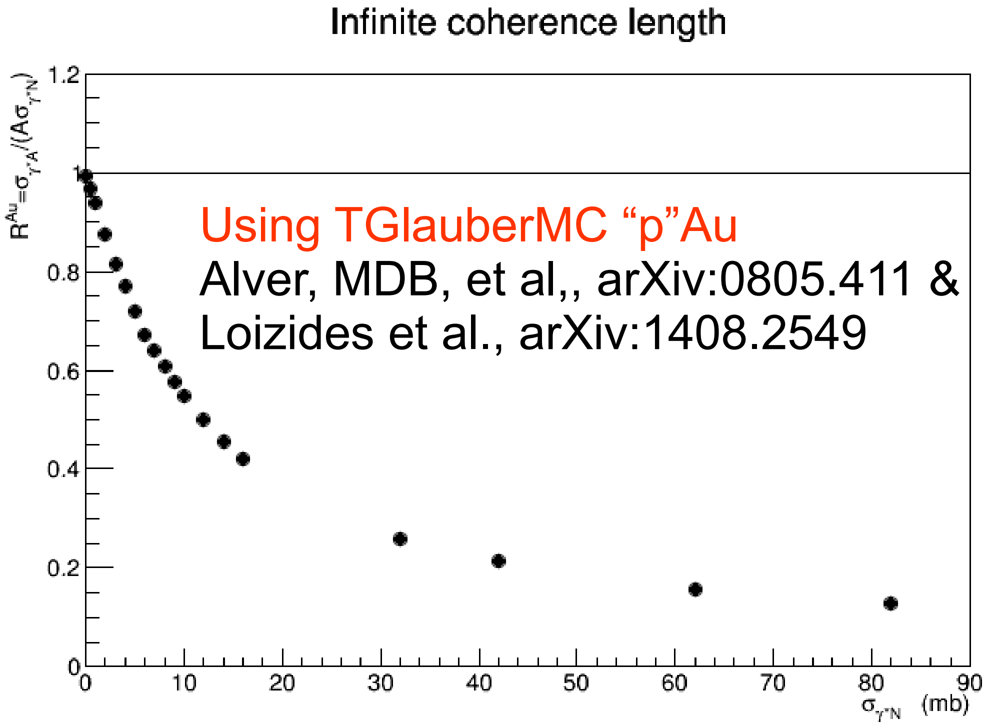
Most of the complications in saturation theory are in predicting the dependence on x, Q^2. With Glauber, we can make a simple map:

$\sigma^A/\sigma^N(x,Q^2) \longleftrightarrow \sigma_{\text{“dipole”}}(x,Q^2) \longleftrightarrow P(N_{coll},b)$

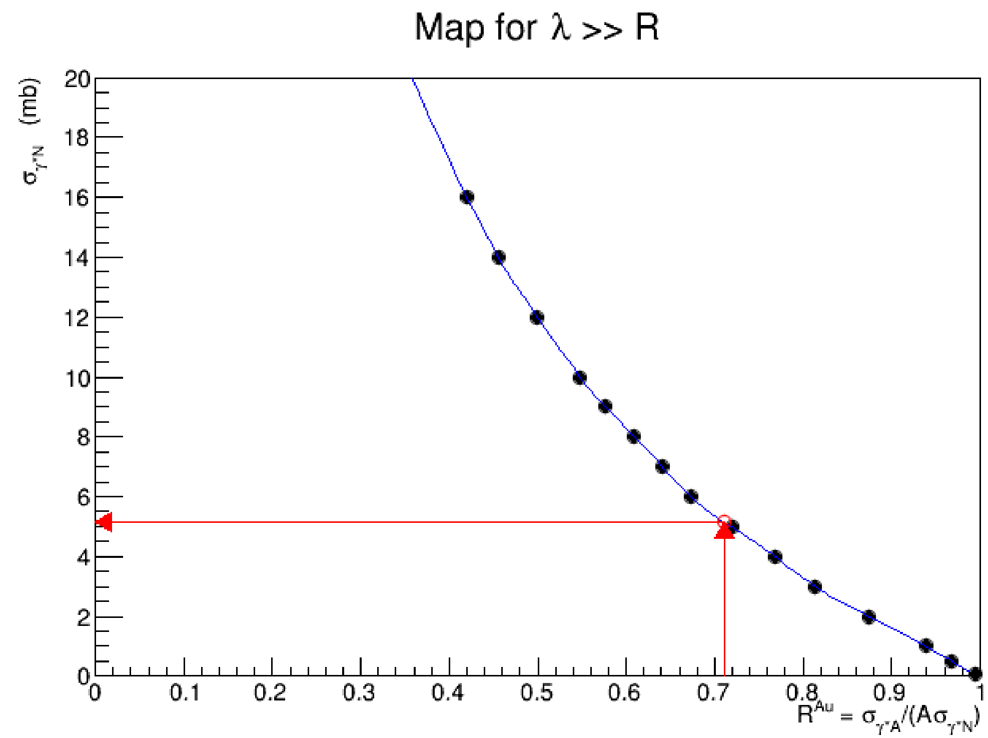




Looking up the appropriate $\sigma_{\gamma^*N}(x,Q^2)$



Flip axes to make map.



Event-by-event, given x & Q^2:

E.g. for $x=0.001$, $Q^2=1.69\ \mathrm{GeV}^2$

$R^{(Au/N)}(x\to 0, Q^2=1.69\mathrm{GeV}^2) \approx 0.711$

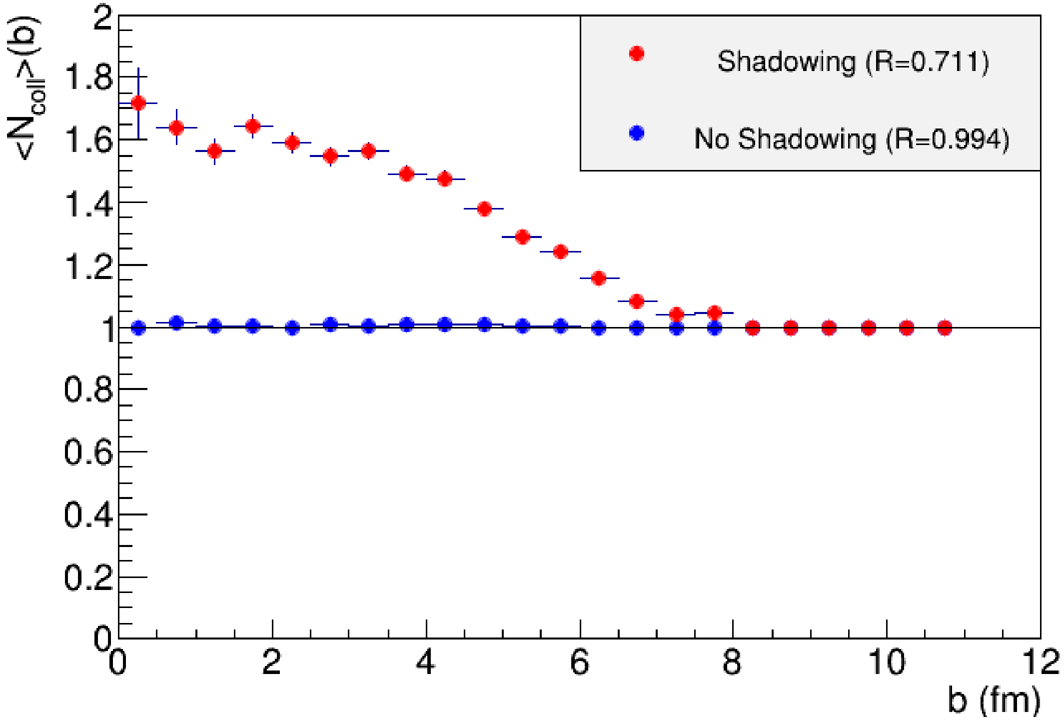
$\sigma_{\text{"dipole"}} = 5.16$ mb

$N_{coll}(b)$ for $Q^2=1.69\ GeV^2, x<<1$

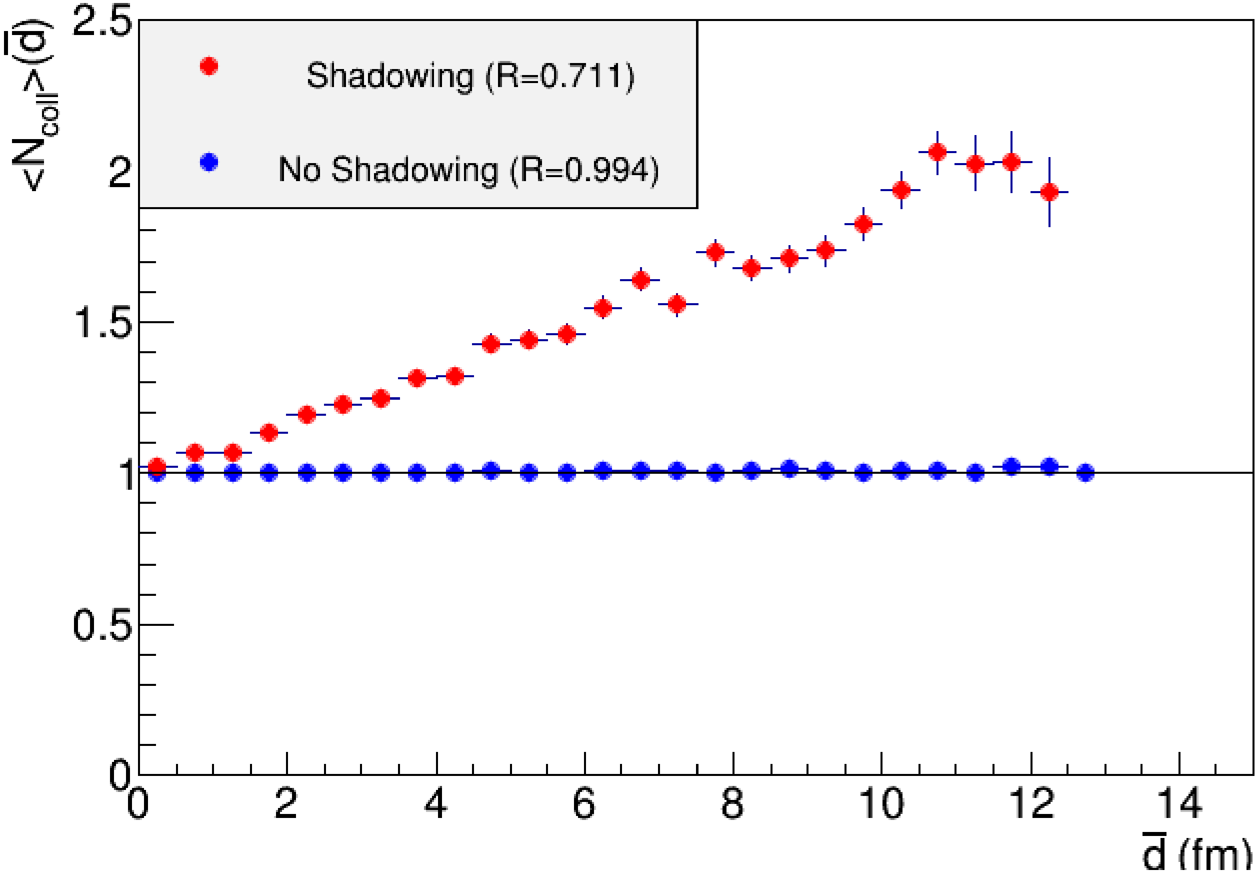
$\sigma^A/\sigma^N(x,Q^2)$ ⟺ $\sigma_{dipole}(x,Q^2)$ ⟺ $P(N_{coll},b)$

- **Big difference between b=0 &**

  b= R_{Au}=6.38 fm at low x,Q^2
- **Geometry tagging easier.**
  Now b is <u>directly</u> correlated with measurable activity
- **Enhanced shadowing (& saturation?) at b=0 (recall $R=1/N_{coll}$).**



Ncoll($\bar{d}$) for Q^2=1.69 GeV^2,x<<1



Visit by Carolina Gajardo?

- Carolina Michel Robles Gajardo
  - PhD student of Will Brooks trying to fit E665 SC data using BeAGLE+PyQM.
  - Visited Raphaël Dupré for a few months in Orsay.
  - She has funds for and would like to visit BNL for a week or two to advance her work.